UNIVERSITY OF SASKATCHEWAN
GE 124.3 – Engineering Mechanics I
FINAL EXAMINATION

TIME: 3 HOURS **December 14, 2005**

Candidates are to answer all questions.

All questions are of equal value.

You are to show your solution in the space below the question.

The reverse side of the page may be used if required.

NAME: ______________________________
(First Name) **(Last Name)**

Section Number (Day/time): ____________________

Student Number: ____________________

Examination Room: ____________________

Marks

1. ________/10
2. ________/10
3. ________/10
4. ________/10
5. ________/10
6. ________/10
7. ________/10
8. ________/10

TOTAL: ________/80

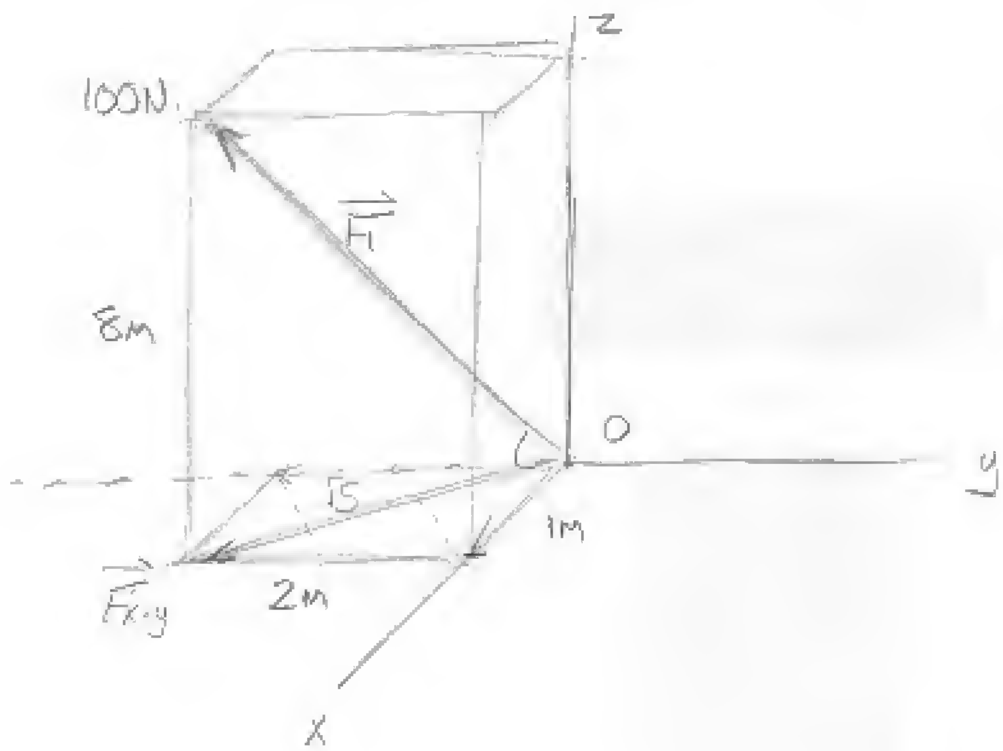
NOTE:
- Make sure you have 8 problems in the exam.
- Use the space below each problem for your solution
- Use the back of previous sheet if more room is required for your solution
- Please place your name at the top of each sheet
- A list of formulas is printed on the last sheet of this exam.

EXAM LOCATIONS:

Section 01 (Tu,Th)	**EDUC GYM**
Section 03 (M,W,F)	**PAC GYM**

Professors: S.L. Barbour, P.B. Hertz, and K. McWilliams

1) A force **F** with a magnitude of 100 N is applied at the origin, **O**, of the **x-y-z** coordinate system and acts towards point **A**, which has (**x, y, z**) coordinates of (1m, -2m, 8m).
   (a) Write **F** as a Cartesian vector.
   (b) Find the magnitude of the projection of **F** onto the x-y plane (F_{xy}).
   (c) Calculate the angle between **F** and the x-y plane.



Check

$\tan\theta = \frac{8}{\sqrt{5}}$

$\theta = 74.38°$ ✓✓

$F_{xy} = F_1 \cos\theta$

$F_{xy} = 100N \cos 74.38°$

$F_{xy} = 26.9\,N$ ✓✓

$\vec{r_1} = \{(1-0)\hat{i} + (-2-0)\hat{j} + (8-0)\hat{k}\}\,m$

$\vec{r_1} = \{1\hat{i} - 2\hat{j} + 8\hat{k}\}\,m$

$r_1 = \sqrt{1^2 + 2^2 + 8^2} = 8.307\,m$

$\vec{F_1} = 100N\left(\frac{\vec{r_1}}{r_1}\right) = 100N\,\frac{\{1\hat{i} - 2\hat{j} + 8\hat{k}\}\,\cancel{m}}{8.307\,\cancel{m}}$

$= 100N\{0.1204\hat{i} - 0.2408\hat{j} + 0.963\hat{k}\}\,N$

$\vec{F_1} = \{12.04\hat{i} - 24.1\hat{j} + 96.3\hat{k}\}\,N$

check: $\sqrt{12.04^2 + 24.1^2 + 96.3^2} = 100$ ✓✓

$\vec{r}_{x\text{-}y} = \{1\hat{i} - 2\hat{j}\}\,m$; $\hat{u}_{x\text{-}y} = \frac{\{1\hat{i} - 2\hat{j}\}\,m}{\sqrt{1^2+2^2}\,m} = \frac{\{1\hat{i} - 2\hat{j}\}}{\sqrt{5}}$

$F_{xy} = \vec{F_1}\cdot\hat{u}_{x\text{-}y} = \{12.04\hat{i} - 24.08\hat{j} + 96.3\hat{k}\}N \cdot \{\frac{1}{\sqrt{5}}\hat{i} - \frac{2}{\sqrt{5}}\hat{j}\}$

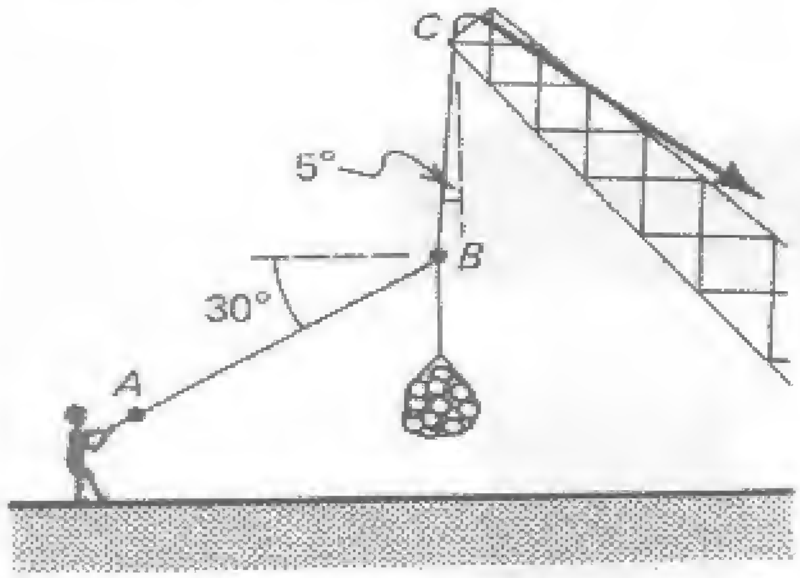
$= \left(12.04\left(\frac{1}{\sqrt{5}}\right) - 24.08\left(-\frac{2}{\sqrt{5}}\right)\right)N = \boxed{26.9\,N}$

$\vec{F_1}\cdot\hat{u}_{xy} = F_1\, u_{xy} \cos\theta$

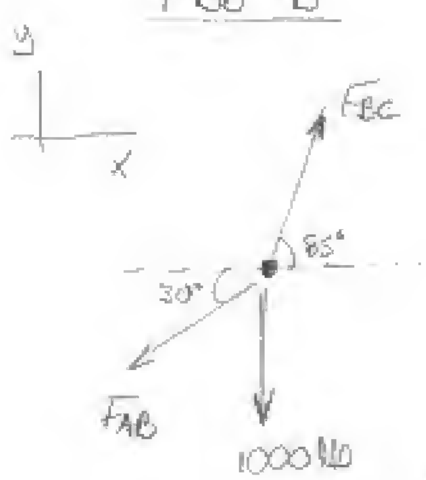
$26.92 = (100N)(1)\cos\theta$

$\theta = 74.38° = 74.4°$ check θ from tan ✓✓

2) A crane is used to pick up a bundle of logs weighing 1000 lb while a person pulls to one side to prevent the load from swaying, as shown below.
(a) Find the tensions in the cables AB and BC.
(b) If the person has a weight of 225 lb and is standing on a surface (such as loose gravel) with a relatively low coefficient of static friction ($\mu_s = 0.45$), will the person be able to stabilize the bundle of logs, or will the person slip?



FBD D



$\Sigma F_x = 0;\ T_{BC}\cos 85^\circ - T_{AB}\cos 30^\circ =$

$T_{BC} = \dfrac{T_{AB}\cos 30^\circ}{\cos 85^\circ}$ (1)

$\Sigma F_y = 0;\ T_{BC}\sin 85^\circ - T_{AB}\sin 30^\circ - 1000\text{ lb} = 0$ (2)

(1)→(2) $\dfrac{T_{AB}\cos 30^\circ}{\cos 85}\sin 85^\circ - T_{AB}\sin 30^\circ = 1000\text{ lb}$

$T_{AB} = 106.398\text{ lb} = \boxed{106.4\text{ lb}}$

$\therefore T_{BC} = 1057.2\text{ lb}$

$\boxed{1.057\times10^3\text{ lb}}$

$\boxed{1057\text{ lb}}$

$\Sigma F_x = 0;\ -F_{req.} + T_{AB}\cos 30^\circ = 0$

$F_{req.} = 92.14\text{ lb}$

$F_s = \mu_s(N)$

$\Sigma F_y = 0;\ T_{AB}\sin 30 - 225\text{ lb} + N = 0$

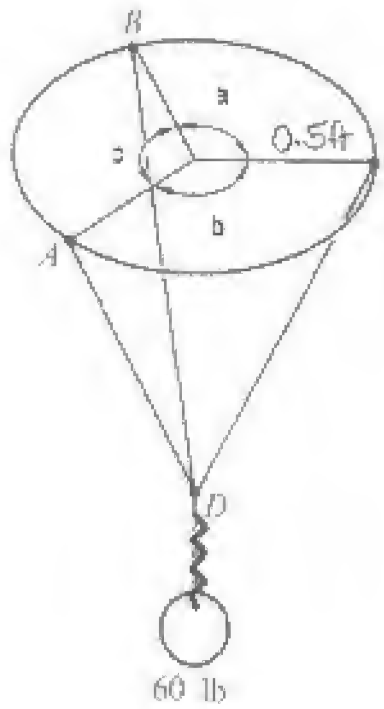
$N = 171.80\text{ lb}$

$F_s = (0.45)(171.80\text{ lb}) = 77.31\text{ lb}$

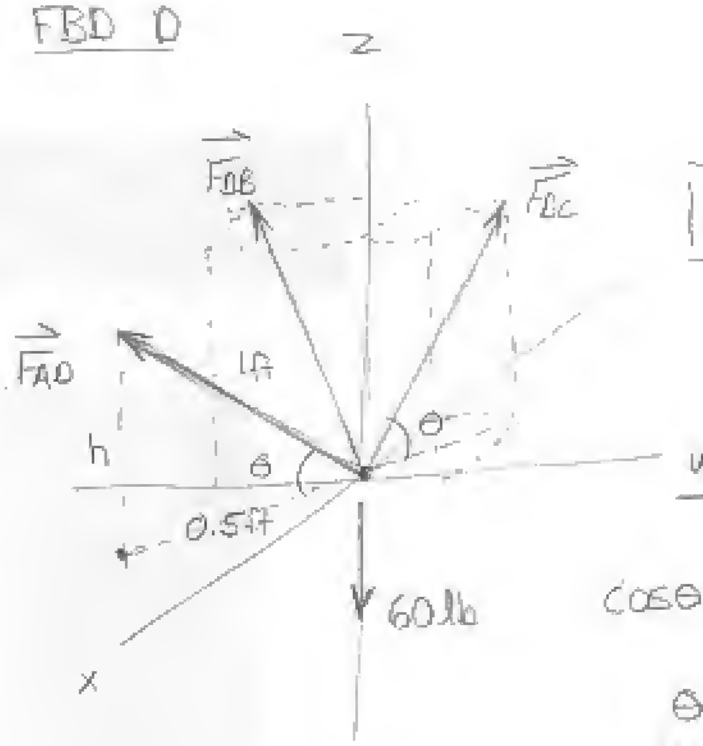
$\therefore$ Man will slip

3) A 60-lb weight is suspended from three ropes (DC, DA, DB), joined at point D, and attached to a circular ring. The diameter of the ring is 1 ft, and the length of each rope is 1 ft.
(a) If the three angles (a,b,c) are all equal, determine the tension in each string.
(b) If the spring connecting the 60 lb weight to point D has a spring constant of 480 lb/ft and unstretched length of 0.25 ft, what is its current length?

$\measuredangle a, b, c = \frac{120^\circ}{3} = 60^\circ$



FBD D



$\boxed{F_{AD} = F_{DB} = F_{DC} = F}$

$\cos\theta = \frac{0.5}{1.0}$

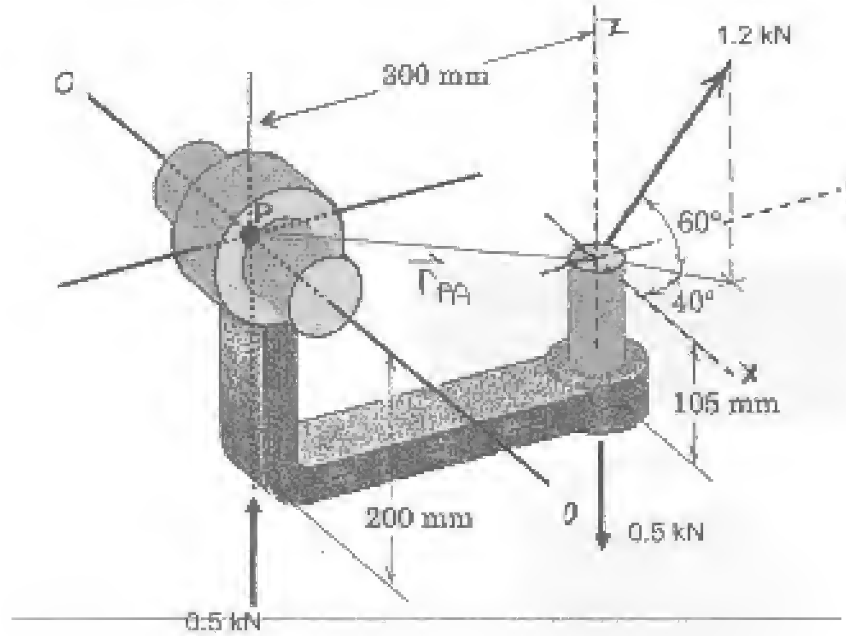
$\theta = 60.0^\circ$

$\Sigma F_z = 0; \quad 3F\sin 60^\circ - 60\,lb = 0; \quad \boxed{F = 23.1\,lb}$

$F_s = ks; \quad 60\,lb = 480\,lb/ft\,(s); \quad s = 0.125\,ft = l' - l$

$l' = 0.125\,ft + 0.25\,ft = \boxed{0.375\,ft}$

4) Compute the total moment, $\mathbf{M}_p$, produced by the 1.2 kN force and the applied 0.5 kN couple forces, about point P. Point P is located at the centre of the shaft shown on the top left portion of the diagram. Also determine the component of this moment about the O-O' axis.



→ recognize couple moment acting in z-y plane; $M = -0.5\,\text{KN}\,(300\,\text{MM})$

$M = -150\ \text{KN}\cdot\text{MM}$

$M = -\{150\,\hat{i}\}\ \text{KN}\cdot\text{MM}$

$\vec{F} = 1.2\,\text{KN}\{\cos 60^\circ \cos 40^\circ\,\hat{i} + \cos 60^\circ \sin 40^\circ\,\hat{j} + \sin 60^\circ\}$

$\vec{F} = 1.2\,\text{KN}\{0.383\,\hat{i} + 0.321\,\hat{j} + 0.866\,\hat{k}\}$

$\vec{r}_{PA} = \{0\,\hat{i} + 300\,\hat{j} - 95\,\hat{k}\}\ \text{MM}$

$$\vec{M}_P = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 300 & -95 \\ 0.383 & 0.321 & 0.866 \end{vmatrix} \begin{matrix} \\ \text{MM} \\ 1.2\ \text{KN} \end{matrix} = \{[300(0.866)(1.2) - (-95)(0.321)(1.2)]\,\hat{i}$$

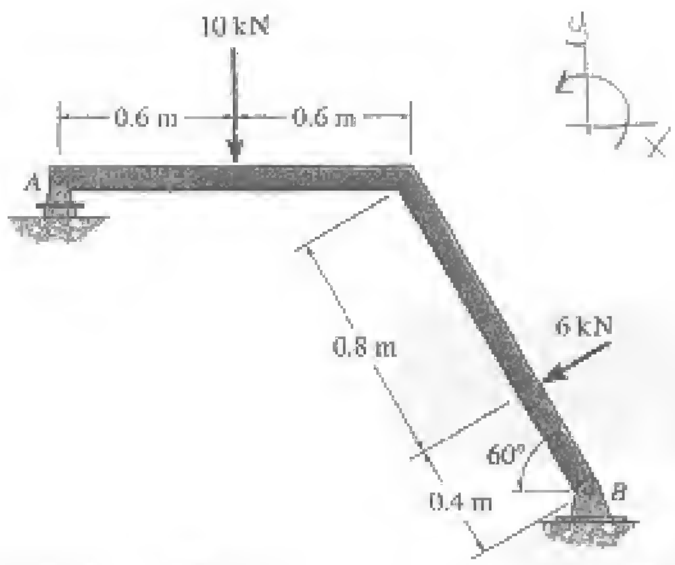
$$-[0-(-95)(0.383)(1.2)]\,\hat{i} + [0 - 300(1.2)(0.383)]\,\hat{k}\}\ \text{KN}\cdot\text{MM}$$

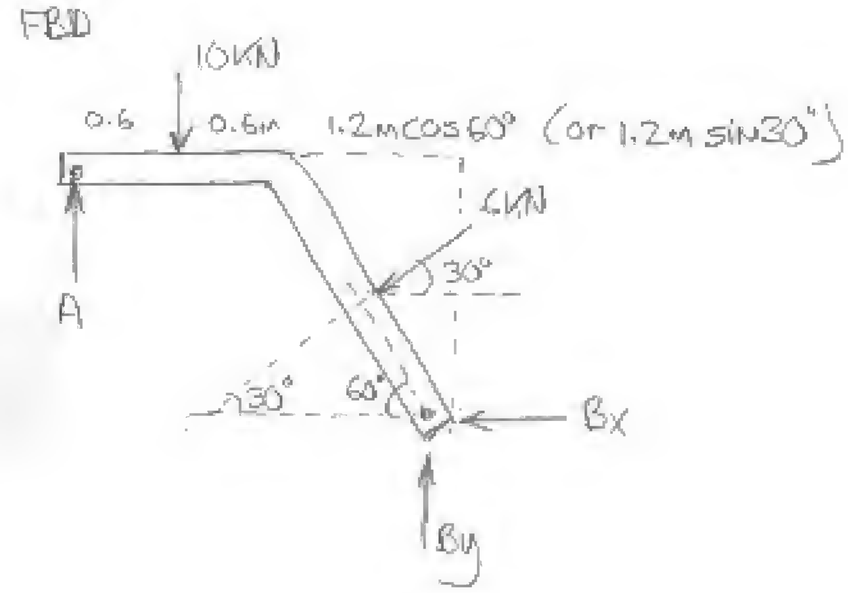
$$-\{150\,\hat{i}\}\ \text{KN}\cdot\text{MM}$$

$\vec{M}_P = \{198.4\,\hat{i} - 43.6\,\hat{j} - 137.1\,\hat{k}\}\ \text{KN}\cdot\text{MM}$ ANS.

recognize that component along O-O' axis is $\vec{M}_{P_{O-O'}} = \{198.4\,\hat{i}\}\ \text{KN}\cdot\text{MM}$ ANS.

5) Determine the normal reaction at the roller A and the horizontal and vertical force components at pin B for equilibrium of the member.





$\Sigma M_B = 0;\ -A(0.6\text{m} + 0.6\text{m} + 1.2\text{m}\cos 60°) + 10\text{ KN}(0.6\text{m} + 1.2\text{m}\cos 60°)$
$+ 6\text{KN}(0.4\text{m}) = 0$

$\boxed{A = 8.00\text{KN}}$ ANS.

$\Sigma F_x = 0;\ -6\text{KN}\cos 30° - B_x = 0$

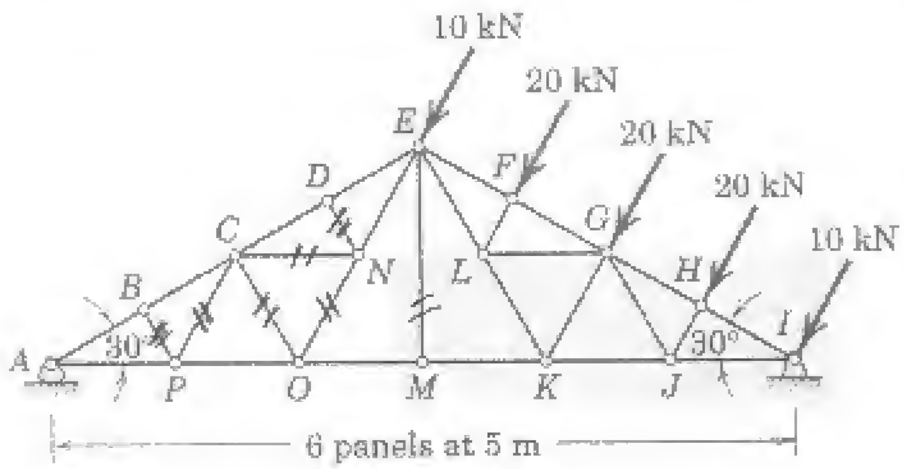
$B_x = -5.196\text{ KN}$

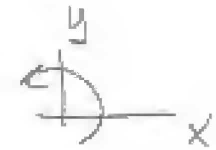
$\boxed{\therefore B_x = 5.20\text{ KN} \rightarrow \text{ on AB}}$ ANS.

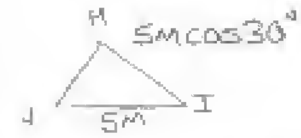
$\Sigma F_y = 0;\ B_y + A - 10\text{KN} - 6\text{KN}\sin 30° = 0$

$\boxed{B_y = 5.00\text{ KN}}$ ANS.

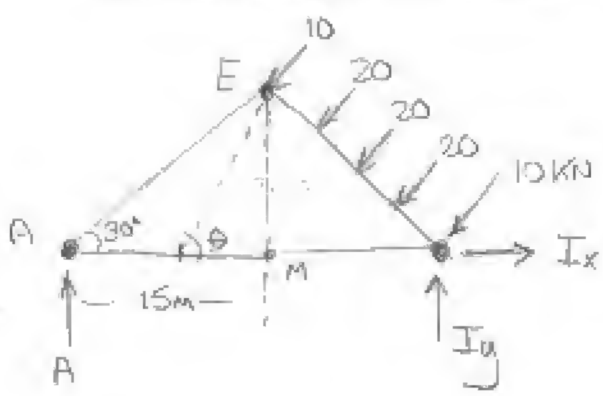
6) Find the forces in members DE, EN, EM, EL, and EF.
(Hint: Watch for zero force members and work from the left side of the truss in order to minimize having to use the applied forces in your solution.)







External Reactions



$\Sigma M_I = 0;\ -A(30m) + 5m\cos 30°[10kN(4) + 20kN(3) + 20kN(2) + 20kN] = 0$

$A = 23.094\ kN$

$\tan 30° = \frac{EM}{15m}$

$EM = 15m \tan 30°$

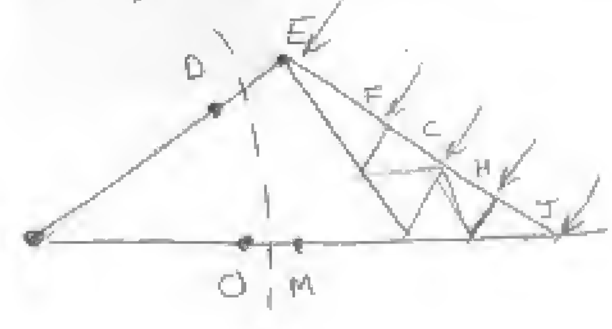
$\tan\theta = \frac{EM}{5m}$

$\tan\theta = 3\tan 30$

$\theta = 60°$

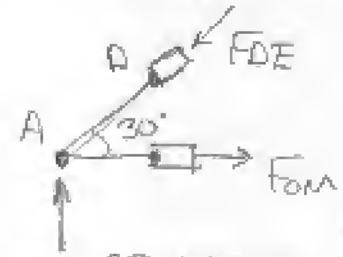
0-Force Members: Start @ B, go to P... D, N, C, O, M

BP, PC, DN, NC, CO, ON(∴EN), EM



$\boxed{F_{EN} = F_{EM} = 0}$ ANS.

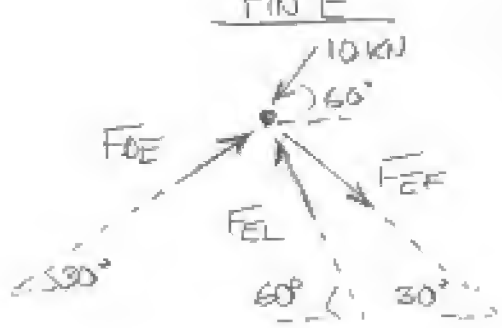
Section A-A



$\Sigma F_y = 0;\ A - F_{DE}\sin 30°;\ F_{DE} = 46.188N$

$\boxed{F_{DE} = 46.2N\ (C)}$

Pin E



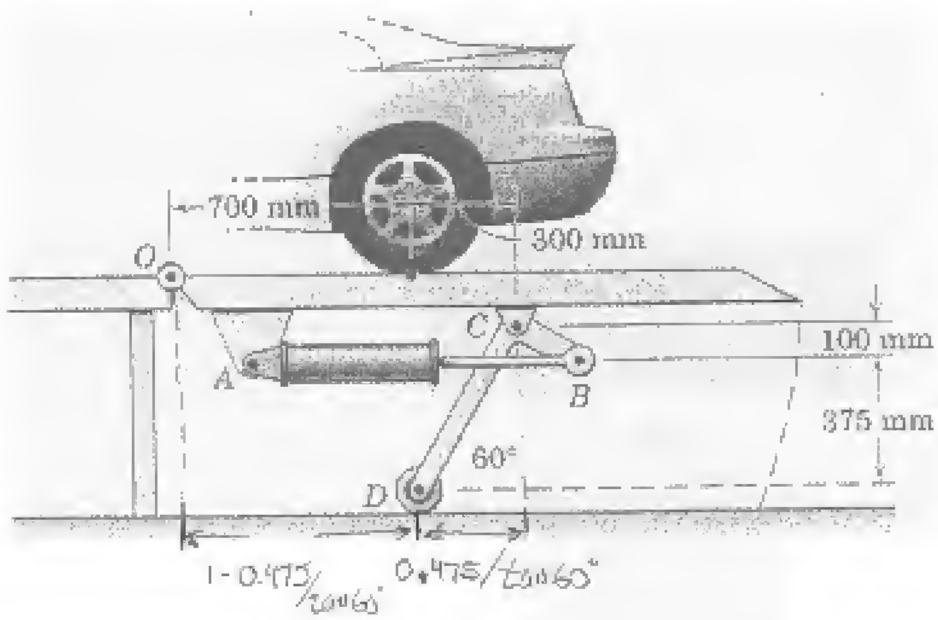
$\Sigma F_x = 0;\ 46.188kN\cos 30° - 10kN\cos 60° + F_{EF}\cos 30° - F_{EL}\cos 60° = 0 \quad (1)$

$\Sigma F_y = 0;\ 46.188kN\sin 30° - 10kN\sin 60° - F_{EF}\sin 30° + F_{EL}\sin 60° = 0 \quad (2)$

$(1) \rightarrow (2)\ F_{EL} = -60.0N(C) \therefore \boxed{F_{EL} = 60.0\ kN\ (T)}$

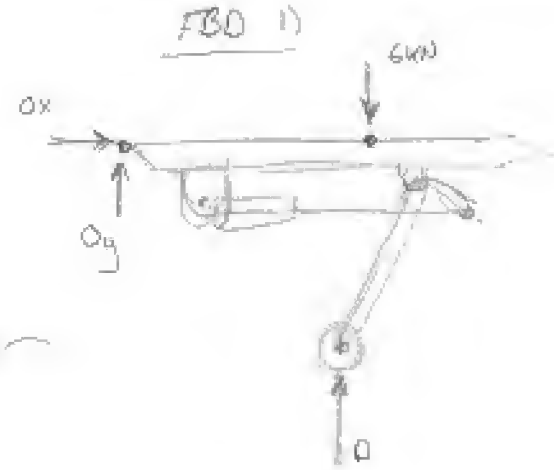
from (1) $F_{EF} = -75.1\ kN\ (T) \therefore \boxed{F_{EF} = 75.1\ kN\ (C)}$

7) The car hoist allows the car to be driven onto the platform, after which the rear wheels are raised. If the total force from both rear wheels is 6kN, determine the force in the hydraulic cylinder AB. Neglect the weight of the platform itself. Member BCD is a right-angle bell crank pinned to the platform at C. (Note: the tire is not directly above the roller at D)



Demonstrates why solving for externals is helpful. If you explode first, the unknowns on OAC are $O_x, O_y, A_x, A_y, C_x, C_y$.

FBD 1)

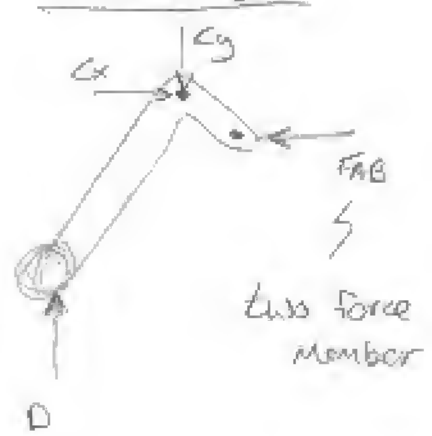


$\Sigma M_O = 0;\ -6000N(0.7m) + D(1.0m - 0.475m/\tan 60°) = 0$

$D = 5787.04\ N$

$\boxed{O_x = 0 \quad O_y = 212.95N}$

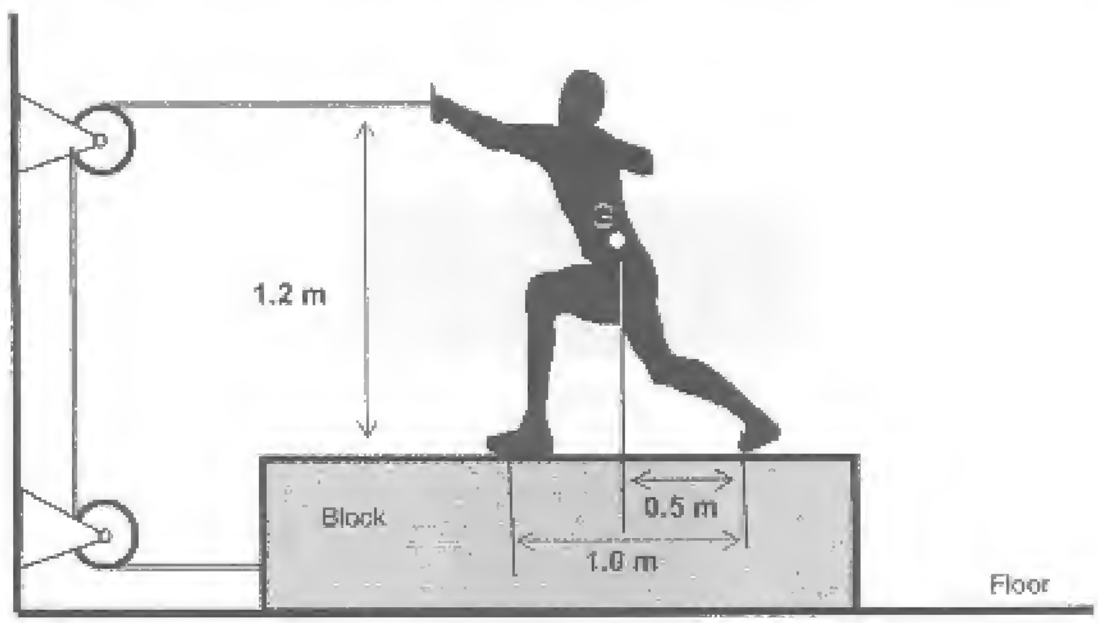
Member BCD



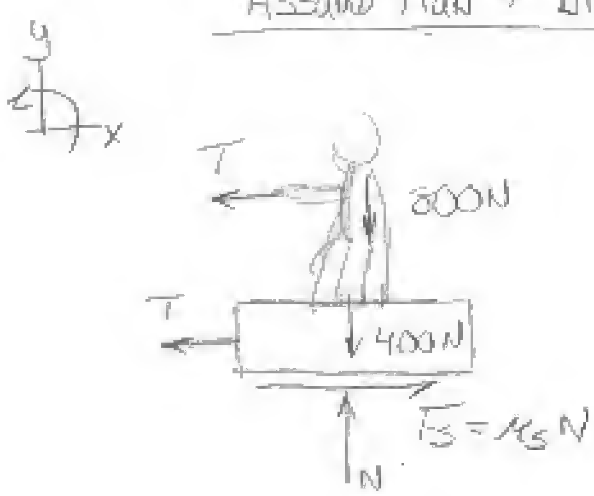
$\Sigma M_C = 0;\ F_{AB}(0.1m) - 5787.04N(.475m/\tan 60°) = 0$

$\boxed{F_{AB} = 15.87\ KN}$

8) A person stands on a block, as shown. The coefficient of static fraction between the person's feet and the block is 0.5. The coefficient of static friction between the block and the floor is 0.25. Assuming the strength of the person is not limiting, determine if the person can move the block by pulling on the rope. The weight of the person is 800N and the weight of the block is 400 N. Assume that the center of gravity of the person is at G.



Assume Man & block slide



variable   unit

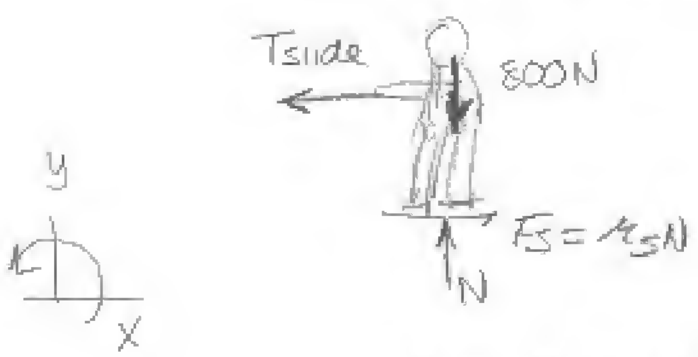
$\Sigma F_y = 0$; $N - (800 + 400)\,N = 0$; $N = 1200\,N$

$F_S = \mu_S N = 0.25(1200\,N) = 300\,N$

$\Sigma F_x = 0$; $2T - 300\,N = 0$; $T_{req'd} = 150\,N$

(to cause M & B to slide)

Check if man slides

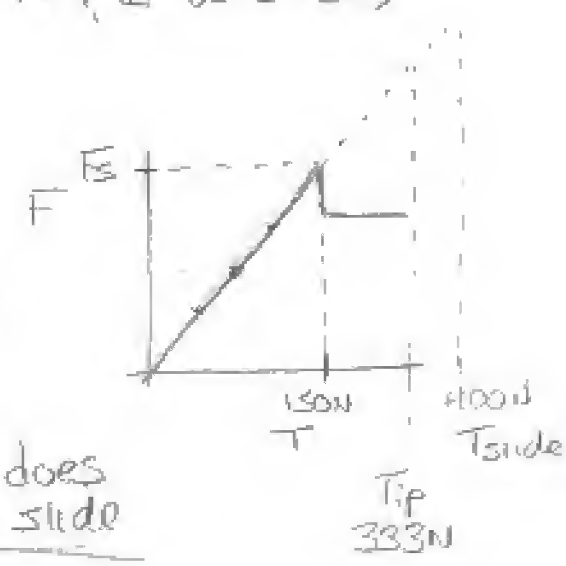


$\Sigma F_y = 0$; $N = 800\,N$

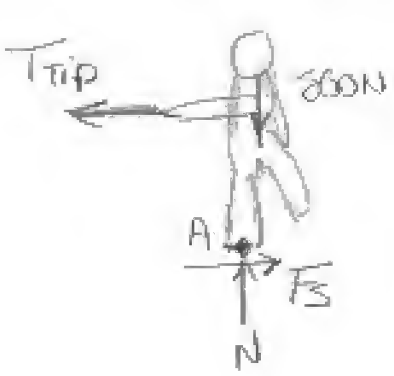
$F_S = \mu_S N = 0.5(800\,N) = 400\,N$

$\Sigma F_x = 0$; $T_{slip} = 400\,N$

$T_{slip} > T_{req'd}$ ∴ Man does Not slide



Check if man tips



$\Sigma M_A = 0$; $T_{Tip}(1.2m) - 800N(0.5m) = 0$

$T_{Tip} = 333N > T_{req'd}$ ∴ Man does Not tip

∴ Man & block move